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Is there a Minimum Caseload that Achieves Acceptable Operative Mortality in Abdominal Aortic Aneurysm Operations?

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Background. Studies have shown correlation between operative workload and mortality for major operations. Is there a threshold for case volume that predicts an acceptable mortality for abdominal aortic aneurysm surgery?

Methods. Hospital Episode Statistics (HES) Data for England between 1997–2002 was analysed using ICD-10 codes I71.x and OPCS-4 codes L16.x-L26.x. Mortality was identified by the method of discharge.

Results. 31078 operations on abdominal aortic aneurysms were studied in 223 NHS Trusts. 6007 in-hospital deaths were identified in both elective and emergency cases (overall mortality rates 7.7% and 40%, respectively). Trusts with large elective workloads had reduced mortality for both elective and emergency operations. Using parabolic regression and logarithmic transformation, 14 elective operations per Trust per year was identified as a cut-off point above which the decrease in mortality rate with increasing case volume was relatively small. A similar effect was not seen with increasing emergency workload alone.

Conclusion. HES data analysis suggests increasing elective workload correlates with lower in-hospital mortality for elective and emergency operations on abdominal aortic aneurysm. Data suggests a range of hospital caseload that correlate with an acceptable elective and emergency mortality rate.

Keywords: Aortic aneurysm; Workload; Threshold; Centralisation; Elective mortality; Emergency mortality; Hospital Episode Statistics; NHS Trust; Parabolic regression; In-hospital mortality.

Background

Over the last 25 years research has focused on the association between workload and mortality in major operative procedures.¹ A systematic review of the magnitude of the volume-outcome association found a consistent difference in mortality rates between high and low-volume providers for aortic aneurysm operations.¹

The *operative volume threshold* that achieves acceptable mortality rate has been of particular importance in aortic aneurysm operations. The Specialised Service National Definition Set in its 2nd edition stated that there are published evidences showing better outcomes when vascular work is carried out by specialists who regularly undertake a *certain minimum number* of procedures.² BMJ Editorials highlighted

this point by referring to the *volume threshold* as the target that the NHS has to focus on and to ensure it has been met.³ To estimate such a threshold, a sound statistical basis should be followed according to VSSGBI recommendations for AAA repair, so that comparisons between different hospitals and individual surgeons would be acceptable and significant.⁴

Using HES data, we have studied the question of whether there is a minimum number of operations that allows achievement of acceptable in-hospital mortality rates in elective and/or emergency abdominal aortic aneurysm repair.

Patients and Methods

Subjects

Incident cases of aortic aneurysm were identified using ICD-10 codes I 71.x (aortic aneurysm and dissection) and OPCS-4 codes L16.x-L26.x (aortic aneurysm repair). We used different methods and software programs for data harvesting and exporting.

HES Identifier generated by the DoH via matching records for the same patient across all the years, using

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a combination of NHS number, Local patient identifier, postcode, sex and date of birth was used to avoid any double counting.⁵ We followed the patients for each data entry to identify the circumstances under which each patient left the consultant's care, either being discharged from the hospital alive, dying in the same hospital admission as operation (in-hospital death), or transferring to another consultant's care without leaving the hospital. In this last case, we followed the patient records up to the final hospital episode in the same admission, when the patient was discharged from hospital or died. Mortality was defined as in-hospital mortality during the same hospital admission as the operation. This may extend beyond 30 days but would reflect more accurately any complications that may occur postoperatively.⁶

The study protocol was reviewed and approved by a local Ethical Committee representative to address issues of confidentiality and feasibility. Following approval we were given access to data specified in our protocol.

Data quality

To ensure appropriate data quality, we followed the definition guidelines of using the HES database as performance indicator in aortic aneurysm operations.⁷ We used the major disease and operative codes in our study rather than the minor potentially miscoded ones, and the trends in data variation rather than absolute values in statistical models. To increase the power of conclusions, we meta-analysed the data to exclude all records of thoracic aneurysm operations as they represent another caseload – quality relation and potentially would influence at least the cut-off number of abdominal aortic aneurysm operations in our model. A review of literature looking at the accuracy of discharge coding system showed that in-hospital mortality rate was coded accurately when validating it against data from the Office of National Statistics.⁸ The systematic review done by Susan *et al.* of discharge coding accuracy showed that median coding accuracy was 90% and 87% for disease and operative coding, respectively.⁹

Results

A total of 144867 hospital records were identified for patients with aortic aneurysm, comprising the records of 93426 individual patients in the six years period 1997–2002. 34049 aortic aneurysm operations were performed. Of the 34049 operations identified, outcome was unknown in 1804 cases. Thoracic procedures were

identified thereafter using the appropriate OPCS-4 codes (I711, I712, I715, I716) and were excluded from our analysis. We were able to follow the final outcome of 31078 abdominal aortic operations which were included in our study. A total of 6007 in-hospital deaths (7.7% and 40% mortality for elective and emergency operations, respectively) were reported. The median age of patients undergoing operation was 72.

Operative volume and mortality rate were calculated in 223 Trusts in the 5 year period. For each Trust, the number of elective and emergency cases, as well as mortality rates in each category was identified.

Elective and emergency workloads were plotted against mortality to obtain the different correlation types (Fig. 1). A trend of reducing mortality rate with increasing workload was apparent for elective but not for emergency operations.

For elective cases, a bivariate correlation procedure to compute Pearson's correlation coefficient with 95% significance level was used. This showed an inverse significant correlation between hospital operative volume and in hospital mortality (-0.315 , $P < .001$).

To reduce the noisiness of HES data and enhance the estimation of correlation coefficient, logarithmic transformation was performed for elective and emergency operations. Plotting and computing the correlation coefficient on the log values showed much better and significant estimation of the negative correlation between elective workload and overall, elective and emergency mortalities (-0.447 , $P < .001$).

We predicted the minimum acceptable elective workload using two different approaches.

Firstly, the distribution of workload:mortality values for each Trust has shown that it follows a parabolic curve rather than a linear one (Fig. 1). This has been confirmed using a best-to-fit regression model in NCSS™ software, which showed this model to be the most appropriate one.

To estimate the number of elective operations required to achieve an acceptable mortality rate, i.e. a workload threshold, the logarithmic values were used to compute the mortality outcome for selected numbers of operations (Fig. 2). This showed that Trusts doing 1 or no elective operations/year report an estimated elective mortality rate of 30%. These mortality rates fall to 20% on doing 2 elective operations/year. To reduce the elective mortality rate by another 10%, Trusts need to do 5 elective operations/year. To achieve the average national mortality rate for elective aortic aneurysm repair of about 7.7% (95% CI, 3.7–12.4), Trusts need to do 14 elective operations/year. No significant decrease in elective mortality rate could be shown when exceeding this threshold elective operative volume.

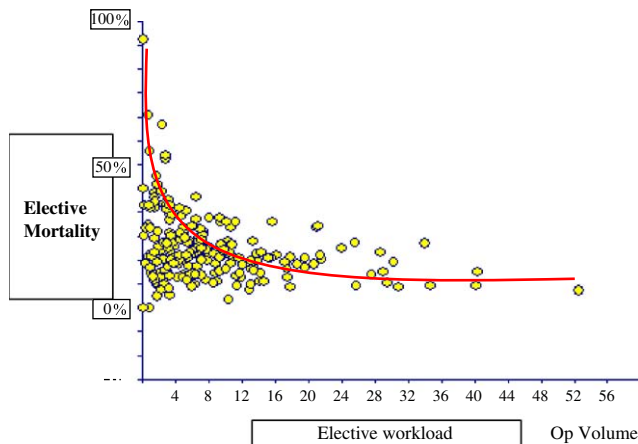


Fig. 1. Trust elective abdominal aortic aneurysm workload plotted against elective mortality rates. Parabolic curve (red) represents the best fitting model for data distribution (see text).

The 14 elective operations/year threshold was tested using a 95% Confidence Interval (CI) bar model, using operative volumes to group different Trusts into two main groups, one doing less than a certain number of operations, the other doing equal to or more than this number (Fig. 2). This model was tested with operative volumes of 6, 8, 12, 14, and 20 elective operations/year. The operative volume at which we achieve minimal overlap of mortality rates, and thus get nearly completely differently behaving groups, was 14 elective operations/year. This confirms the logarithmic model conclusions and adds to the threshold estimation techniques used.

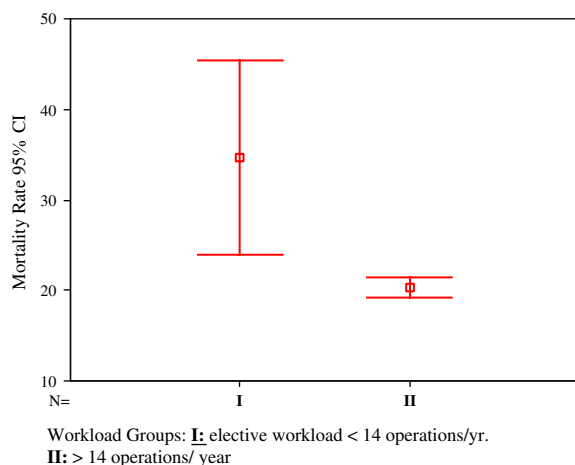


Fig. 2. 95% Confidence Interval (CI) bar Model, using operative volumes to group different Trusts according to their mortality estimation. This shows no overlap at 14 elective operations/year.

Discussion

This study is one of the largest population-based studies to confirm the relationship between hospital workload and mortality rates. Careful analysis and interpretation of HES data supports the hypothesis that there is a significant correlation between increasing hospital operative caseload and decreasing in-hospital mortality for aortic aneurysm operations. Our study results, therefore, are consistent with other population-based studies in the US.^{9–17} The definition of low- or high-volume hospitals in those studies, however, varied remarkably, partly due to the aggregation of cases using a pre-defined value, or their assumption that the correlation is of a linear type. This does not reflect the actual distribution of data in a non-linear parabolic pattern as we have shown.

The underlying explanation of this correlation remains unclear. Luft *et al.* (1979) hypothesized that the volume-outcome relationship is a consequence of a “learning-by-doing” or “practice makes perfect” basis.¹⁸ The idea behind this is that the more you perform a given task, the better you get in performing it. In 1987, Luft, Hunt and Maerki¹⁸ proposed another explanation which they called “selective referral” where physicians and hospitals with better outcomes attract more patients, the “selective-referral pattern” hypothesis. Although the medical literature has largely assumed that the learning-by-doing hypothesis was the correct explanation of the results, more detailed studies^{19–20} using examination of the patterns of selected variables on hospital volume as well as simultaneous equation models to test the relative importance of the two explanations have suggested that the two models are valid, although the “learning-by-doing” model plays a more important role in explaining the differences across hospitals in their risk-adjusted outcomes.

Several potential pitfalls of centralising cases to high volume hospitals have been noticed.²⁰ For example, the focus on high volume providers may be a “distracting priority,” and similar improvements in care may be achieved through more traditional local quality improvement measures or by increasing the workload in other vascular operations. This might explain the fact that centers with low aortic aneurysm caseload may also achieve good results. Moreover, hospitals with high volumes may use that data to misrepresent their experience in the absence of true outcomes data. Likewise, the narrowing of the choice of providers may negatively impact patient satisfaction and override patients’ preferences for care (for example, if patients are forced to travel long distances to receive care at a high volume centre). The effect of the

individual surgeon's workload on the outcome and the interaction with the overall hospital workload cannot be accurately analysed from the present study, where the main focus is on the hospital workload:outcome relationship. A separate complementary study is required to fully analyse the relation between individual surgeon volume and both surgeon and hospital outcome in the UK. The introduction of the new Consultant Identifier in the HES database potentially allows for such analysis, which will be an important subject of a further research.

Changing practice based on the interpretation of data linking workload and improved outcomes is a complex task; it is essential to involve patients, hospitals and communities, as well as payers and employers. The final model should take all other quality factors into consideration to achieve a quality outcome^{21–25}: the likelihood of experiencing complications, the readmission rate, the length of stay, the case-mix risk adjustment,¹⁸ guidelines and protocols for modelling and managing vascular services,^{2,23} guidelines of transporting critically ill adults,²⁴ the experience of merging multiple hospitals/services,^{25,26} as well as patient and staff satisfaction. Using operative workload as a "proxy" for other quality indicators is appropriate only if the operative workload threshold limits have been taken into consideration. Considering all these factors will undoubtedly have major impacts on the way health planning and centralisation models are developed.

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